Changing needs for Ph.D.'s

After having been led to believe that the Ph.D. degree would be a key to an exciting career, doctorate-holders in science and engineering are now having difficulty in locating jobs

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New trends are developing in the United States' supply of scientific and engineering manpower. Students appear to be losing interest in science and engineering; at the same time, there is concern about an oversupply of Ph.D.'s. Underlying this oversupply is a disturbing fact of life: In the 1970s, the universities and the defense and space industries will have very limited need for new Ph.D.'s. The situation calls for an agonizing reexamination and reorientation of both the content of and attitudes toward the Ph.D. degree.

The doctorate is the preferred level of preparation for those who wish to pursue an academic career in science and engineering or a career in industrial research. (The term "science" is used throughout to denote the natural sciences—that is, physical, mathematical, and biological; social and behavioral sciences are not included.) Figure 1 illustrates the number of Ph.D.'s awarded in engineering and science since 1957. The ratio of Ph.D. to B.S. degrees awarded six years earlier is plotted in Fig. 2. These latter curves indicate the approximate percentage of recipients of the B.S. degree who successfully completed work for the Ph.D.* The data in Figs. 1 and 2 apply only to men; the number of women who carry their studies to the doctoral level in science and engineering is so small as to be statistically unimportant.

The growth rates of Ph.D.'s, as shown by the curves of Fig. 1, are all remarkably high. Table I shows that, over the period from 1960 to 1968, average annual increases in excess of 10 percent were typical; in engineering, these increases reached 17 percent.

After many years during which Ph.D.'s appeared to be in short supply, people with new Ph.D.'s in certain areas are having difficulty in locating satisfactory jobs. The problem is not one of unemployment, since Ph.D.'s can always compete successfully for jobs normally filled by M.S. and B.S. graduates. (This is verified by a study of the employment status in early 1970 of 1967–68 and 1968–69 recipients of Ph.D. degrees in the natural and social sciences and engineering, as carried out by the Office of Scientific Personnel, National Research Council.[1])

Rather, the problem lies in the inability to achieve their job expectations, after having been led by teachers and advisors to believe that investing time and money in the Ph.D. would be the key to an exciting and attractive career. The disillusionment is greatest for those students who studied at the most prestigious schools, because their expectations were the highest.

What has been happening can be understood with the aid of Table II, which shows the activities of Ph.D. scientists and engineers in the labor force in 1968. Of the 48 700 engineering, mathematical, and physical science (EMP) Ph.D.'s in this census, 46 percent were employed by universities and 41 percent were engaged in research and development outside a university. Thus, nearly all of these individuals were engaged in teaching, R&D, or both. The last column of Table II shows that the Ph.D.'s produced in 1968 increased the number of EMP Ph.D.'s in the labor force by 9.7 percent (not including attrition by death, retirement, and so on).

During most of the 1960s, undergraduate enrollments in science and engineering were increasing rapidly. Government-supported academic research and graduate

I. Rate of growth of Ph.D.'s (U.S. Office of Education)

Field	Ph.D. Output 1960	Ph.D. Output 1968	Average Annual Increase, percent
Engineering	783	2921	17
Physical sciences	1776	3405	8.5
Physics	477	1234	12
Chemistry	1000	1584	6
Mathematical sciences	285	895	15
Engineering, mathematical, and physical sciences	2844	7221	12
Biological sciences	1086	2347	10

II. Activities of employed Ph.D.'s in 1968[2]

Field	University, percent	Nonuniversity R&D, percent	Nonuniversity Other, percent	1968 Increment New Ph.D.'s, percent
Engineering	45	37	18	14.6
Mathematics	82	7	11	11.4
Physical sciences	40	49	11	7.4
Engineering, mathematical, and physical sciences	46	41	13	9.7
Biological sciences	75	9	16	7.5

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* The data in Fig. 2 need to be corrected for foreign students who received their undergraduate training abroad. The information required to make this adjustment is not available, but it is estimated that something like 10 to 20 percent of doctoral degrees fall into this category, with the fraction varying from field to field. Also, these curves are not corrected for students who received the Ph.D. in a field different from that in which they received the B.S. degree.

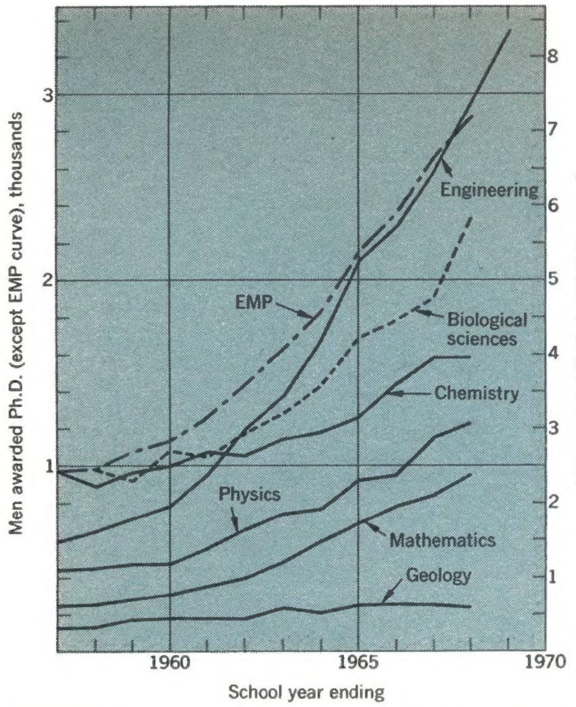

FIGURE 1. Doctorates awarded to men in selected fields. EMP denotes the engineering, mathematical, and physical sciences. (U.S. Office of Education statistics)

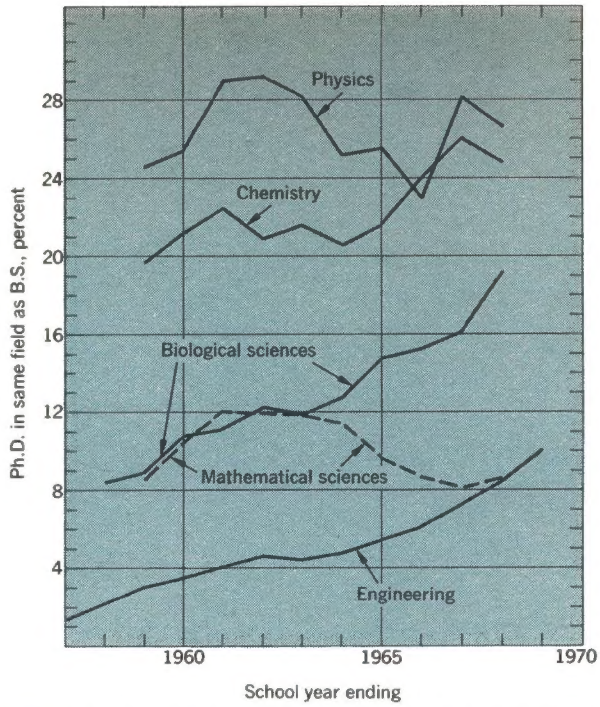

FIGURE 2. Doctorates awarded to men in selected fields as a percentage of baccalaureate degrees awarded six years earlier. (U.S. Office of Education data)

enrollments were rapidly growing, as were government expenditures for defense and space work. As a consequence, there was a steadily expanding demand for new Ph.D.'s, and the growing number of Ph.D.'s produced each year (Fig. 1) was readily absorbed, until the 1969–70 academic year.

In 1969–70, things suddenly became different. First, the number of openings for young Ph.D.'s at universities suddenly and sharply dropped. This was partly because, beginning in 1969–70, the number of students studying science and engineering abruptly leveled off. Concurrently, government funds for academic research leveled off, so that research and associated graduate activities in universities stopped expanding; in some cases, they decreased. All institutions of higher education have financial problems; as a result, they are running increasingly tighter financial operations.

Second, government expenditures on industrial R&D for defense and space, after having risen steadily during most of the 1960s, leveled off in the past two years. As a result, few new scientists and engineers with Ph.D.'s are being employed in these areas. Moreover, employment in defense industries is also suffering serious dislocations as some of the large programs are phased out.

Although some of the present conditions may not be normal because of such factors as Vietnam and anti-inflation efforts, there is no prospect of the pre-1969 employment situation for Ph.D.'s returning at any time in the foreseeable future.* The number of undergraduate students in science and engineering shows no prospect of increasing rapidly, as it did in 1955 to 1969; rather, it can be expected to level off and then decline. About the best that can be hoped for is that research funds will increase in proportion to increases in the gross national product; they will probably not regain the annual growth rate of 15 percent that obtained from 1960 to 1968.

Third, government funding for missiles and other technologically complex defense hardware, as well as space, can be expected to drop off as funds are diverted to pressing social needs. Although there is much talk about the need for science and technology in solving social problems such as housing, pollution, and inner-city decay, such talk has not yet produced very much in the way of dollars for academic or industrial research in science and engineering.

This does not mean that the need for individuals who are highly trained in science and engineering will decrease in the future. Rather, the present difficulties revolve around the fact that the primary markets for new Ph.D.'s are no longer academic institutions and basic research. Instead, new Ph.D.'s are employed by industry for applied work that is less related to defense and space. Meanwhile, the orientation of people receiving the Ph.D. has not changed to reflect the new situation.

In the past, about half of the Ph.D.'s in the EMP fields have found employment in industry (Table II). However, although industry absorbed all the Ph.D.'s it was able to attract, it has never been entirely happy with the available product. Thus, at a meeting in September 1969, attended by 70 of the corporate asso-

* A stimulating discussion of this matter is given by J. P. Martino,[3] who points out that, when the rate of growth of science appreciably exceeds that of society as a whole, the growth rate of science must soon level off. On the arbitrary assumption that this leveling off became effective in 1968, Martino shows that "U.S. universities will find that they are required to turn out a much smaller number of graduates. . .The science staffs of U.S. universities are already larger (as of 1968) than the staffs which would be required in 1975. . . ." This gloomy day will unquestionably be pushed further into the future by broadening the scope of activity of those possessing scientific training; nevertheless, this day of ultimate reckoning hangs like a threatening sword over the head of the scientific establishment.

ciates of the American Institute of Physics, 93 percent of those present felt that "the training of physicists at the Ph.D. level is strong but narrow." All of them agreed with the statement: "Graduate research supervisors instill attitudes in their students that result in low prestige for applied research among young physicists." Likewise, 79 percent agreed that "narrow training in highly specialized techniques . . . is not adequate for the rapidly changing frontiers of applied research." Finally, 93 percent agreed that "at present, physics professors recommend research in industry only to their poorer students; [however] the importance of some practical problems merits the best efforts."[4]

The exact situation varies from field to field, from subfield to subfield, and from one thesis supervisor to another. However, the fact remains that, even in engineering, which is generally more closely tied to the industrial world than are the science fields, a not insignificant fraction of the Ph.D.'s have characteristics similar to those of the physicists.

Industry's extensive need for highly trained individuals is not now being met. Industry requires broadly trained, creative individuals who are flexible in their outlook, are capable of working in interdisciplinary teams, and are prepared to work on problems that need to be solved rather than on problems that are invented on the campus. The situation is well stated by the National Science Board as follows[5]:

> There is need for a basic reexamination of the assumption underlying doctoral training in the physical sciences. The present doctorate was designed primarily as training for an academic career... and is based on the assumption that there should be no difference in the training of those heading for a university teaching or research career and of those aiming primarily at . . . industrial research.
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> The problem may not be so much one of the content of the educational experience, as it is of the attitudes and values communicated by the graduate school. ... There is increasing belief that a somewhat different type of training, equivalent in intellectual stature but aimed more suitably for nonresearch careers, should be available. Such training would still involve basic research experience, but possibly with greater breadth and variety and less specialization than the present degree. In the light of evolving industrial needs and changing social priorities, a more nearly fixed time period, less sharp specialization, and less emphasis on an original discrete contribution to knowledge should all be considered as possibilities in any review of the doctoral program. Consideration should be given to providing the student with a wider diversity of opportunities as he pursues his education.... Deep specialization in an original research contribution might well be reserved for postdoctoral experience.

It is clear that the production of Ph.D.'s in science and engineering cannot continue to expand in the 1970s as it did in the 1960s. In fact, the great consumers of Ph.D.'s in the 1960s, namely, academic institutions and defense and space activities, will require substantially fewer new Ph.D.'s during the 1970s. Although industrially funded research will continue to grow at perhaps twice the rate of increase of the gross national product, this is not enough to take up the slack. Accordingly, if the magnificent educational establishment that now exists in the United States for producing highly trained scientists and engineers is not to wither away, new outlets must be found for its product. This means searching out new needs and hitherto neglected opportunities, and then developing the manpower markets thus defined.

This situation is quite different from that of the past, when professors typically trained young people along the lines of their own interests and had no trouble placing their protégés in satisfying positions. As the National Science Board says, the situation calls for reexamination and reorientation of both the content of and attitudes toward the Ph.D. degree. This will be agonizing and unsettling. The redeeming feature is that out of the stress and strain and pain and difficulties will come new ideas and new directions. This is not the time to complain about our present difficulties; it is, rather, the time to seek out new opportunities and to make the most of them.

REFERENCES

1. *Science*, vol. 168, p. 930, May 22, 1970.
2. "Science and engineering doctorate supply and utilization 1968–1980," National Science Foundation NSF 69-37, Government Printing Office, Washington, D.C., 1969.
3. Martino, J. P., *Science*, vol. 165, p. 769, Aug. 22, 1969.
4. Strassenburg, A., "Supply and demand for physicists," *Phys. Today*, vol. 23, p. 23, Apr. 1970.
5. "The physical sciences," report of National Science Board, Government Printing Office, Washington, D.C., 1970.

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